(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 863 392 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
09.09.1998 Bulletin 1998/37

(51) Int. Cl.[6]: G01L 9/00

(21) Application number: 97830093.7

(22) Date of filing: 04.03.1997

(84) Designated Contracting States:
AT BE CH DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE

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(54) A method of manufacturing pressure microsensors

(57) The method described provides for the formation of a region of silicon dioxide on a substrate (11) of monocrystalline silicon, the epitaxial growth of a silicon layer, the opening of holes (14') in the silicon layer above the silicon dioxide region, and the removal of the silicon dioxide which constitutes the region by means of chemical attack through the holes (14') until a silicon diaphragm (12'), attached to the substrate (11) along the edges and separated therefrom by a space (15), is produced. In order to form an absolute pressure microsensor, the space has to be sealed. To do this, the method provides for the holes (14') to have diameters smaller than the thickness of the diaphragm (12') and to be closed by the formation of a silicon dioxide layer (16) by vapour-phase deposition at atmospheric pressure.

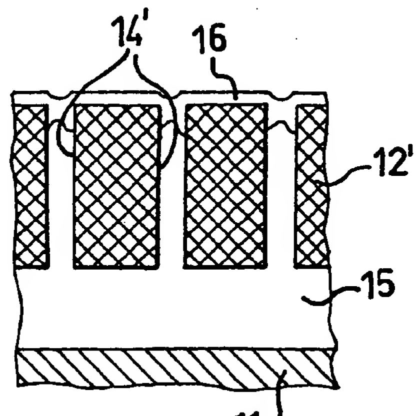

FIG.6

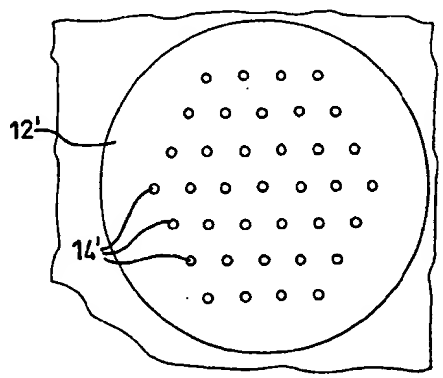

FIG.5

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Description

The present invention relates to methods of manufacturing semiconductor devices and, more particularly, to a method of manufacturing a pressure microsensor on a silicon substrate, as defined in the preamble of Claim 1.

Two techniques are known for producing pressure, acceleration and similar microsensors and provide for the formation of thin diaphragms on a substrate of semiconductor material. One of these techniques is based on the machining of a wafer of semiconductor material on both of its faces, essentially by means of anisotropic chemical attack (bulk micromachining). The other is based on machining on a single face of a wafer of semiconductor material by the deposition of thin layers and the selective removal of a portion of an inner or buried layer with the use of isotropic chemical attack (surface micromachining). The latter technique is particularly suitable for the integration of the sensor with processing circuits associated therewith.

A method of manufacturing microstructures by the "surface micromachining" technique is the subject of European patent application No. 96830437.8 filed by the Applicant on 31.07.96 and is described briefly below with reference to Figures 1 to 4. This method provides for the formation of a silicon dioxide region 10 on a monocrystalline silicon substrate 11 (Figure 1), the formation by epitaxial growth of a silicon layer in which polycrystalline silicon 12 grows on the silicon dioxide region 10 and monocrystalline silicon 13 grows on the rest of the substrate (Figure 2), the formation of holes 14 in the polycrystalline portion of the silicon layer (Figure 3), and the removal of the silicon dioxide region 10 by chemical attack with hydrofluoric acid through the holes 14 (Figure 4) so as to form a space 15 beneath a diaphragm of polycrystalline silicon 12'.

The object of the present invention is to produce an absolute pressure sensor with the use of the "surface micromachining" technique. This requires the formation of a structure similar to that obtainable by the known method described above, but in which the space defined by the polycrystalline silicon diaphragm is closed hermetically.

This object is achieved by the method defined and characterized in Claim 1.

The invention will be understood better from the following detailed description of a preferred embodiment thereof, given by way of non-limiting example with reference to the appended drawings, in which:

Figures 1 to 4 show, in section, a portion of a silicon wafer in successive stages of processing in accordance with the known method described above,

Figure 5 is a plan view of a portion of a silicon wafer having a structure similar to that shown in section in Figure 4 and formed in accordance with the invention,

Figure 6 shows, in section and on an enlarged scale, a detail of the structure of Figure 5 at a subsequent processing stage, and

Figure 7 shows, in plan and very schematically, an absolute pressure microsensor produced by the method of the invention.

According to the invention, the method is carried out in the manner described in the European patent application cited above, as far as the removal of the buried silicon dioxide region, that is, until a structure similar to that shown in Figure 4, with a polycrystalline silicon diaphragm 12' attached to the silicon substrate 11 along its edges, separated therefrom by a space and perforated at several points, is obtained. In a preferred embodiment, the diaphragm 12' is circular and has a plurality of circular holes 14' distributed uniformly about its surface, as shown in Figure 5. The number of holes is selected so as to ensure complete removal of the oxide, but without appreciable alteration of the mechanical characteristics of the diaphragm, with a relatively short attack time of, for example, from 5 to 10 minutes. In the embodiment described, the thickness of the diaphragm 12' is about 10μm and the thickness of the silicon dioxide region removed, and hence of the space 15, is abut 2μm. According to the invention, the widths of the holes for the attack of the oxide beneath the diaphragm 12' should be smaller than the thickness of the diaphragm. In this example, this width, that is, the diameter of each hole 14', is about 2μm.

The next step of the method according to the invention is the formation of a layer 16 of silicon dioxide on the polycrystalline silicon of the diaphragm, as shown in Figure 6. This layer is produced by vapour-phase deposition (CVD) at atmospheric pressure with the use of a mixture of silane and oxygen in proportions of 1 to 10, possibly also containing doping compounds such as diborane or phosphine, at a temperature of between 350 and 450°C, preferably 380°C, and for a period of about 2 minutes.

In these conditions, and with the hole diameter indicated above, the silicon dioxide is formed on the surface of the diaphragm and, naturally, on that of the surrounding monocrystalline silicon, but does not form or forms only to a negligible extent, inside the space. In practice, the reagents accumulate at the mouths of the holes 14', forming a layer of silicon dioxide which gradually reduces the widths of the holes until it closes them completely, thus sealing the space. It is thought that this result is due to the fact that, in the operative conditions indicated, the reagents are not absorbed by the silicon surfaces and their mean free path is much greater than the diameters of the holes.

In addition to circular holes, elongate, that is slot-shaped or rectangular, holes with widths of about 2μm have been tested. Naturally, holes of any other shape may be used with the same results, provided that the width satisfies the condition indicated above.

In the preferred embodiment of the method according to the invention, air at atmospheric pressure remains inside the space 15. However, in different processing conditions, another gas may remain at atmospheric pressure inside the space without this affecting the characteristics of the resulting microsensor.

The method continues with a photolithography step to remove the layer of silicon dioxide, except from the area of the diaphragm, by standard operations for the formation of other electronic components on the same substrate. For example, a layer of silicon nitride may be deposited and then removed selectively to form the active areas of a MOS integrated circuit in the epitaxial monocrystalline silicon layer.

In order to complete the formation of the sensor, means, for example, piezoresistive elements, are required for detecting mechanical deformation of the diaphragm 12'. According to a preferred embodiment, particularly when the sensor is to operate at high temperature, a layer of doped polycrystalline silicon is deposited on the nitride covering the diaphragm and is then defined by normal photolithographic processes so as to produce four identical, elongate doped regions with the function of piezoresistors R1-R4 on edge regions of the diaphragm 12', as shown schematically in Figure 7. Electrical connections are then formed in order to form a wheatstone bridge, as shown in the drawing. Two resistors R2 and R4 of the bridge are oriented radially so that, when the diaphragm is acted on by a positive pressure, their resistance increases owing to the piezoresistive effect, and the other two resistors, R1 and R3 are oriented tangentially so that their resistance decreases with the same stress. The pressure is therefore detected as an unbalance of the bridge, that is, as an electrical voltage between two points A and B of the bridge when the other two points C and D are connected to a voltage supply Va.

Alternatively, the resistors may be formed directly on the diaphragm 12' by local doping of the polycrystalline silicon of which it is formed. In this case, the doping is preferably carried out before the operations to close the holes 14'.

Claims

1. A method of manufacturing a pressure microsensor on a silicon substrate (11), comprising the following steps:

   forming a region (10) of a selectively removable material on the substrate (11),

   forming a silicon layer (12, 13) on this region (10) and on the substrate (11),

   forming holes (14) in the silicon layer (12, 13) above the region (10),

   removing the material from the region (10) by selective chemical attack through the holes (14) until a diaphragm (12') of predetermined thickness constituted substantially by a portion (12') of the aforesaid silicon layer, attached to the substrate (11) along the edges and separated therefrom by a space (15), is produced, and

   forming means for detecting mechanical deformation of the diaphragm (12'),
   characterized in that the holes (14') have widths smaller than the thickness of the diaphragm (12'), and in that, after the diaphragm (12') has been produced, a layer (16) of silicon dioxide which closes the holes (14') is formed by vapour-phase deposition at atmospheric pressure on the portion of the silicon layer which constitutes the diaphragm.

2. A method according to Claim 1, in which the holes (14') are distributed substantially uniformly on the portion (12') of the silicon layer which is to constitute the diaphragm.

3. A method according to Claim 1 or Claim 2, in which the space (15) contains air at atmospheric pressure.

4. A method according to any one of Claims 1, 2 and 3, in which the holes (14') are circular.

5. A method according to any one of Claims 1, 2 and 3 in which the holes (14') are substantially rectangular.

6. A method according to any one of the preceding claims, in which the thickness of the diaphragm (12') is about 10μm and the widths of the holes (14') are about 2μm.

7. A method according to any one of the preceding claims, in which the selectively removable material is silicon dioxide and the chemical attack for its removal is carried out with hydrofluoric acid.

8. A method according to any one of the preceding claims, in which the step of the formation of a silicon layer (12, 13) is an epitaxial growth in which monocrystalline silicon grows on the silicon of the substrate and polycrystalline silicon grows on the removable material.

9. A method according to any one of the preceding claims, in which four elongate, doped regions with

the function of piezoresistors (R1-R4), and respective electrical connections, are formed on the diaphragm (12') to form a Wheatstone bridge, the orientation of the elongate, doped regions being such that a pressure on the diaphragm (12') causes an electrical unbalance of the bridge.

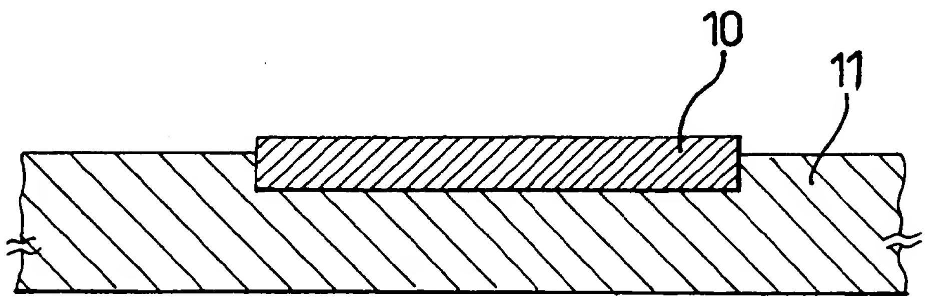

FIG.1

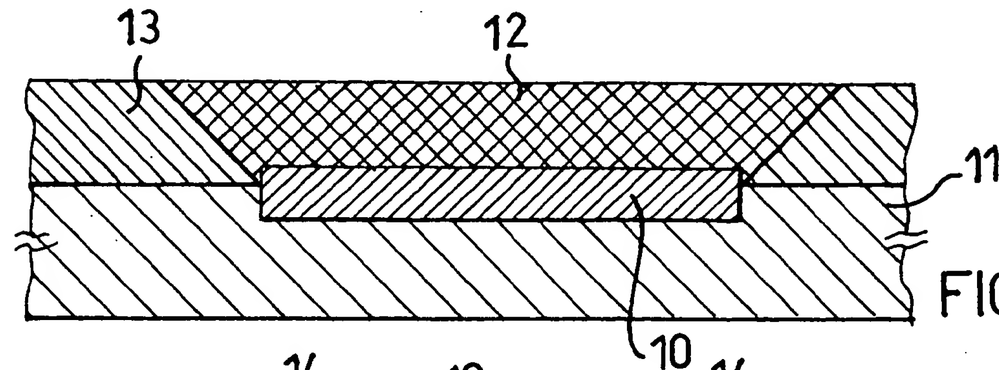

FIG.2

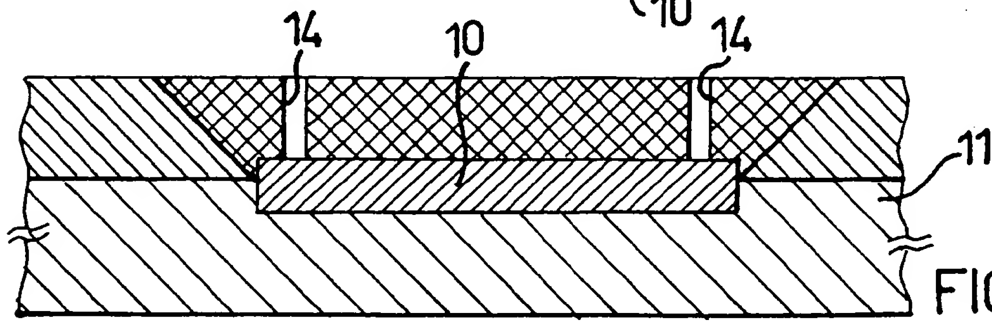

FIG.3

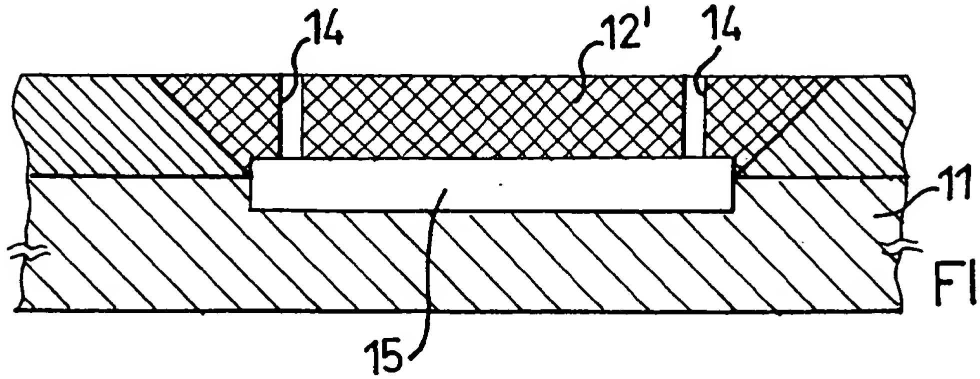

FIG.4

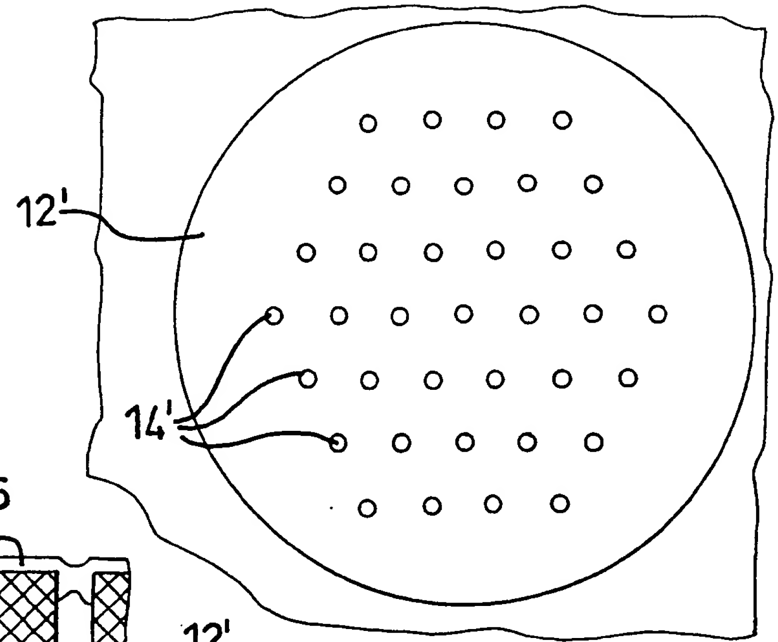

FIG.5

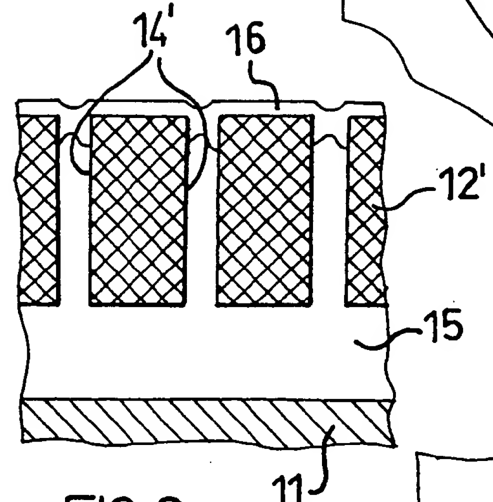

FIG.6

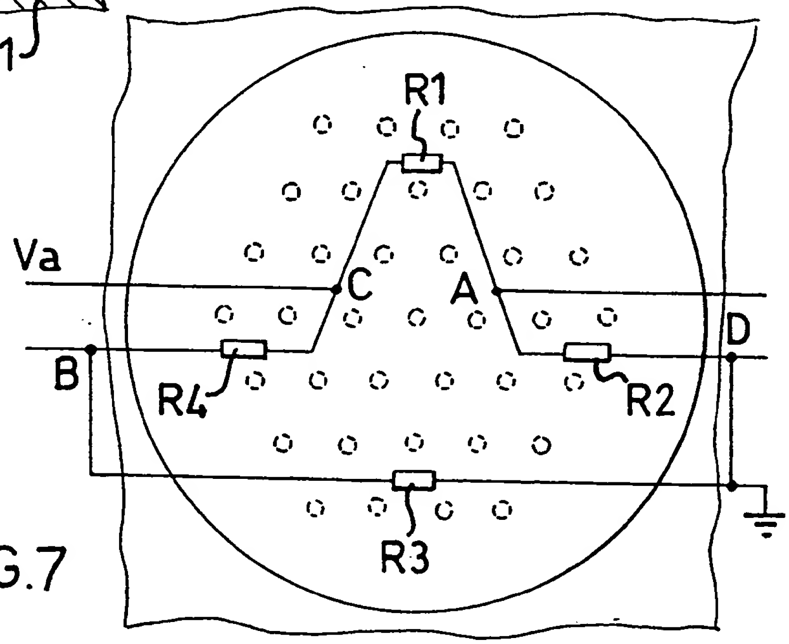

FIG.7

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 97 83 0093

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
Y	US 5 095 401 A (ZAVRACKY PAUL M ET AL) 10 March 1992 * column 3, line 16 - column 5, line 22; figure 1A.1E * ---	1,4,7-9	G01L9/00
Y	JOURNAL OF VACUUM SCIENCE & TECHNOLOGY B (MICROELECTRONICS PROCESSING AND PHENOMENA), SEPT.-OCT. 1990, USA, vol. 8, no. 5, ISSN 0734-211X, pages 1068-1074, XP000654541 BHUSHAN B ET AL: "Stress in silicon dioxide films deposited using chemical vapor deposition techniques and the effect of annealing on these stresses" * page 1068, paragraph I * ---	1,4,7-9	
Y	US 4 849 071 A (EVANS ALAN G R ET AL) 18 July 1989 * the whole document * ---	1,4,7-9	
A	EP 0 624 900 A (DELCO ELECTRONICS CORP) 17 November 1994 * column 7, line 29 - column 10, line 46; figures 2A-2C * * column 11, line 43 - column 12, line 30; figure 5 * ---	1,2,4-6,9	TECHNICAL FIELDS SEARCHED (Int.Cl.6) G01L
A	US 5 369 544 A (MASTRANGELO CARLOS H) 29 November 1994 * abstract; figures 4A-4H * ---	1,4,7	
A	EP 0 727 650 A (VAISALA OY) 21 August 1996 * abstract; figure 1 * -----	1,2,5,7	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	9 June 1997	Gerken, S

CATEGORY OF CITED DOCUMENTS

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